Drought, fire and tree mortality
Can our forests at Redwood Creek take the heat?

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U.S. Department of the Interior
U.S. Geological Survey

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science for a changing world

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Outline

- **Current patterns and dynamics in old-growth forests**
- **Early findings from redwood forests**
- **So what?**

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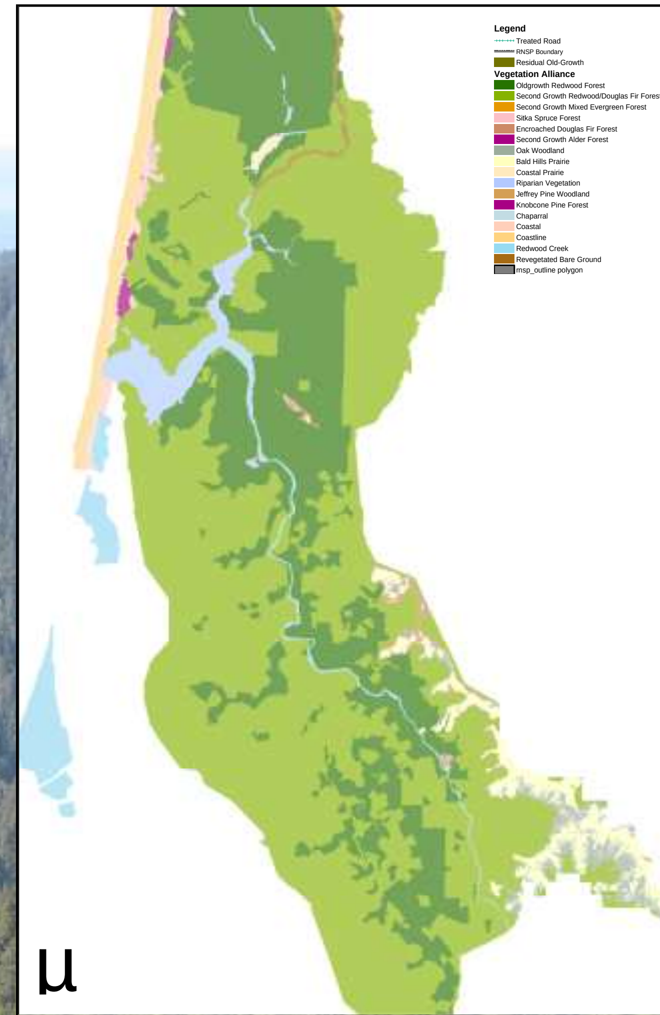
Old-growth redwood forests

< 10% of all coast redwood forests remain in old-growth stage.

~ 45% of remaining old-growth redwood forests (~ 160 km^2) found in Redwood National and State Parks (RNSP).

RNSP vegetation map



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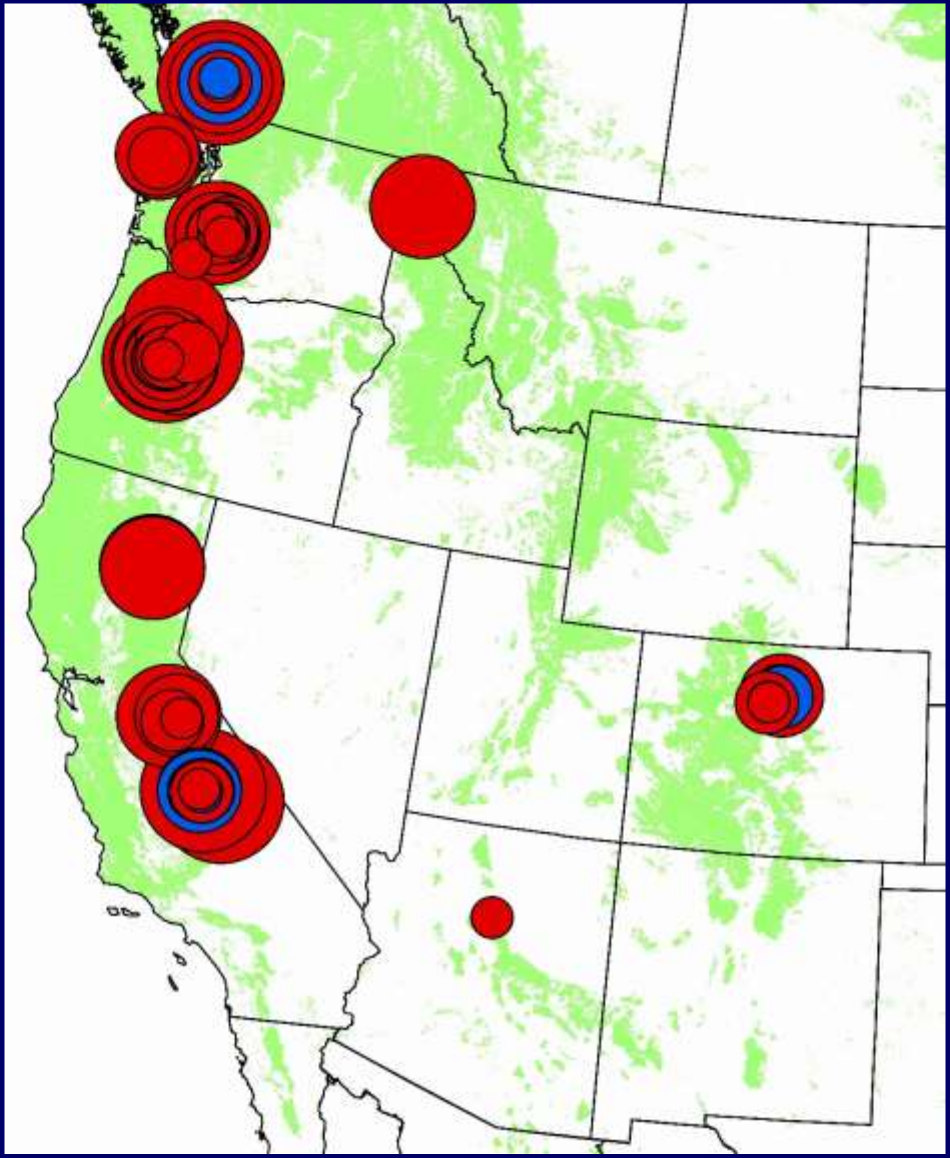
Tree mortality rates are increasing in the western US



Findings

- 76 plots in undisturbed old forests
- observed from ~1981 to ~ 2004
- 87% of plots increasing mort. rate
  P <0.0001
- mort. rate ~18 yr DOUBLING
  period
- temporal trend, P <0.0001

van Mantgem *et al.* 2009, *Science*

Tree mortality rates are increasing in the western US

-- a mechanistic understanding

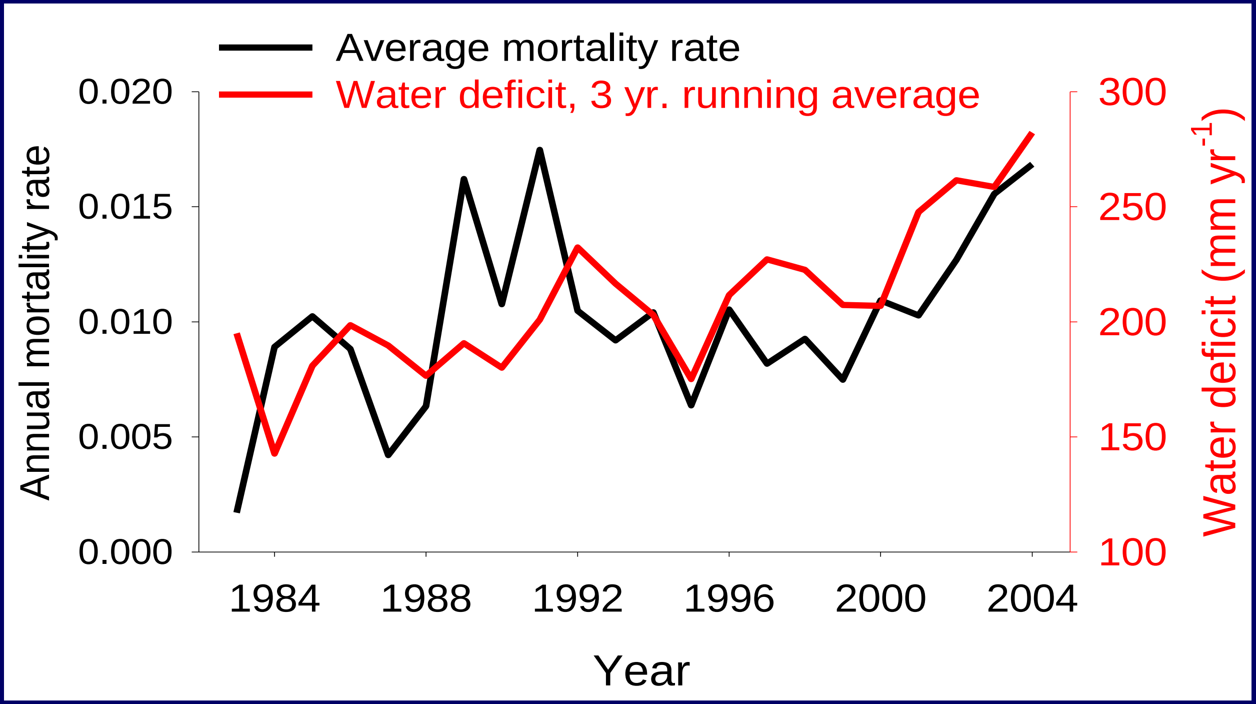
Stress
mortality
(standing dead:
insects, fungi,
or no symptoms)

Related to water deficit

Stress-biotic mortality

$\beta_{year} = 0.01$, s.e. = 0.01, $P = 0.58$

$\beta_{D} = 0.005$, s.e. = 0.001, $P = 0.0002$



van Mantgem & Stephenson 2007, *Ecol. Lett.*

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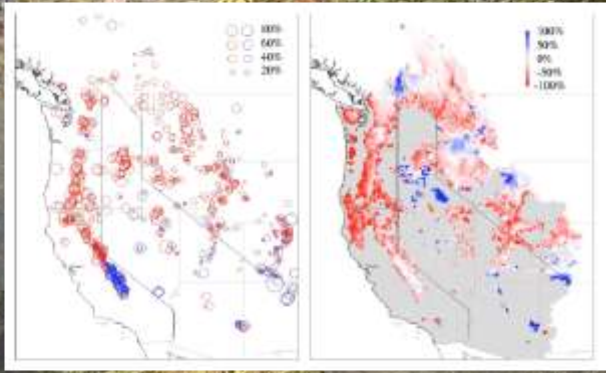
Changes in western North America

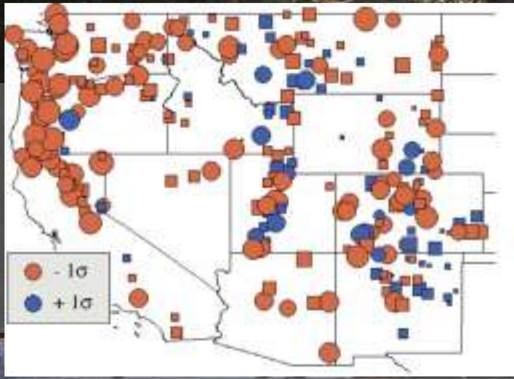
Hydrologic changes in the West

Snowpack has been decreasing



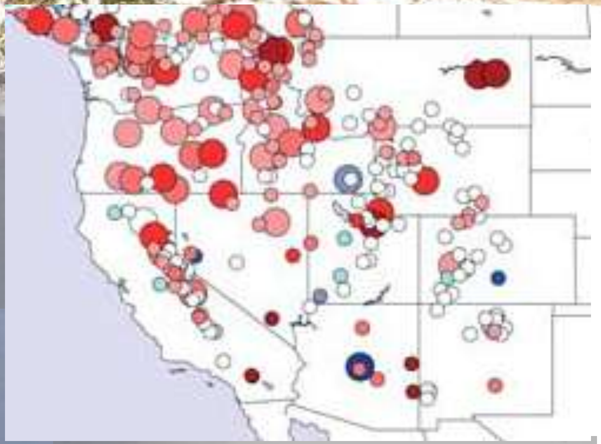
Mote *et al.* 2005

More precipitation falling as rain vs. snow



Knowles *et al.* 2006, *J. Clim.*

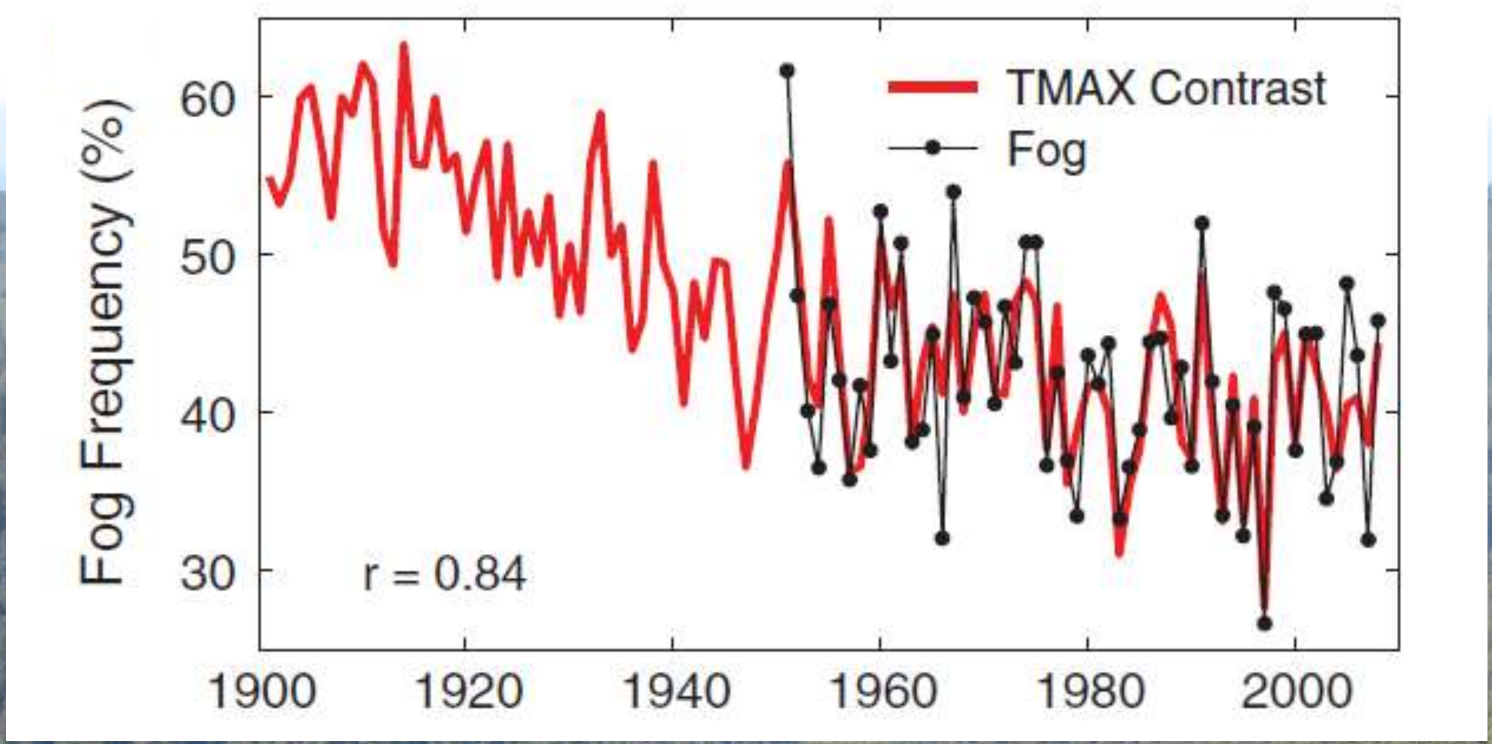
Spring streamflow has been arriving earlier



Stewart *et al.* 2004, *Clim. Change*

Changes in old-growth coastal redwood forests

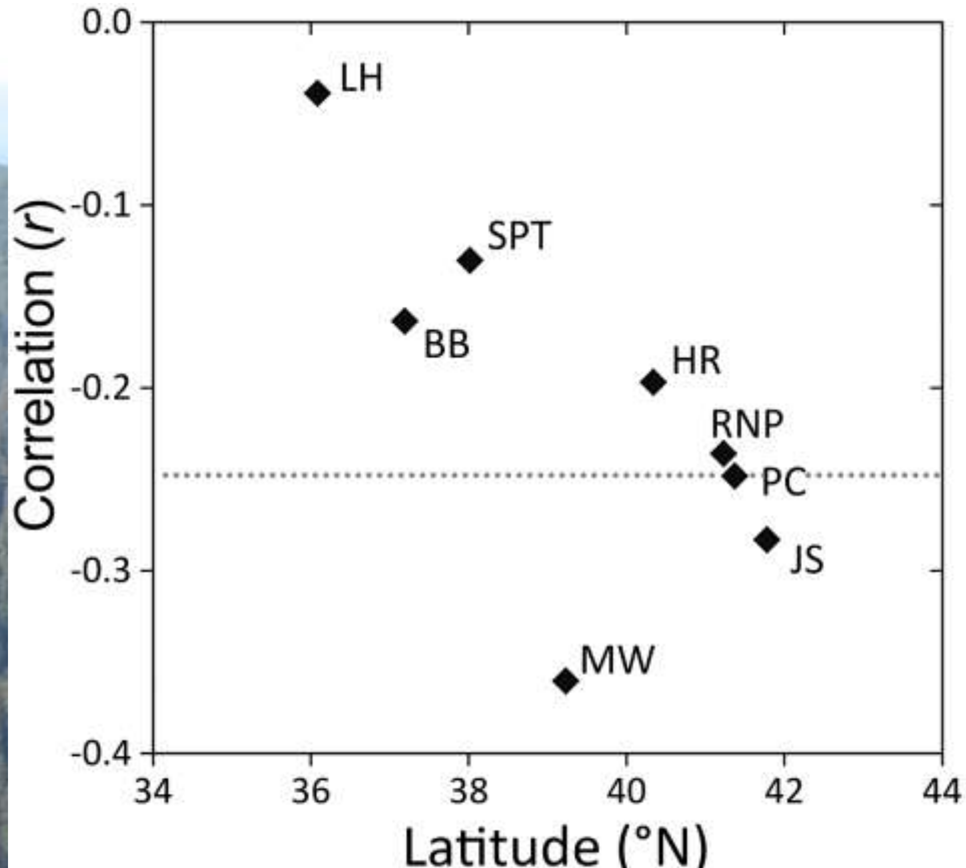
33% reduction in fog frequency since the early 20th century



Johnstone & Dawson 2010, *Proc. Nat. Acad. Sci.*

Changes in old-growth coastal redwood forests

- redwood radial growth increased with decreasing summer cloudiness (i.e., airport fog)
- significant (*P*<0.01) at three locations in northern California



Carroll *et al.* 2014, *PloS one*

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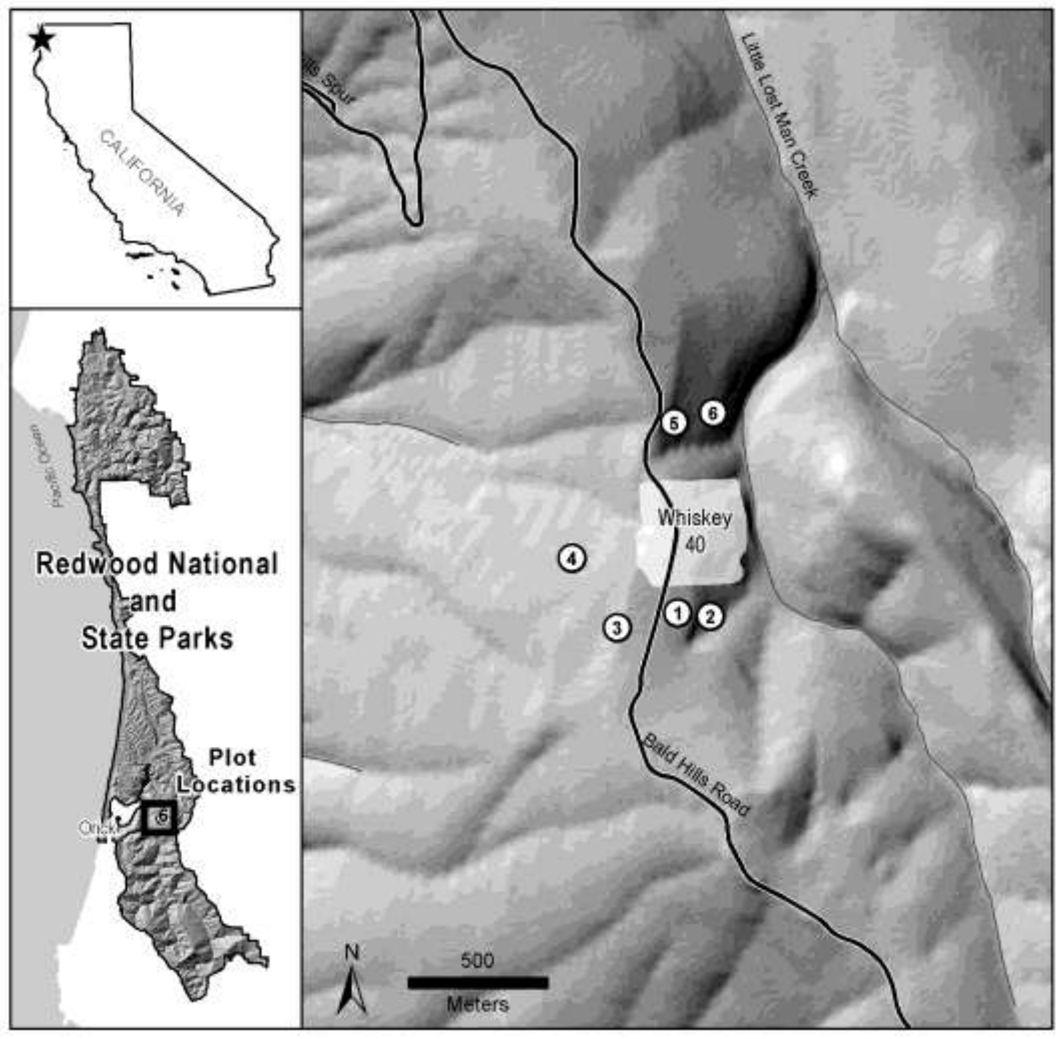
One hectare forest monitoring plots

Plot statistics

<u>1995</u>
Surveys measured and mapped all stems ≥20 cm DBH.

<u>2010</u>
Remeasured all stems ≥20 cm DBH, recording mortality, recruitment and radial growth.



van Mantgem and Stuart, 2012 PSW-GTR-238

One hectare forest monitoring plots

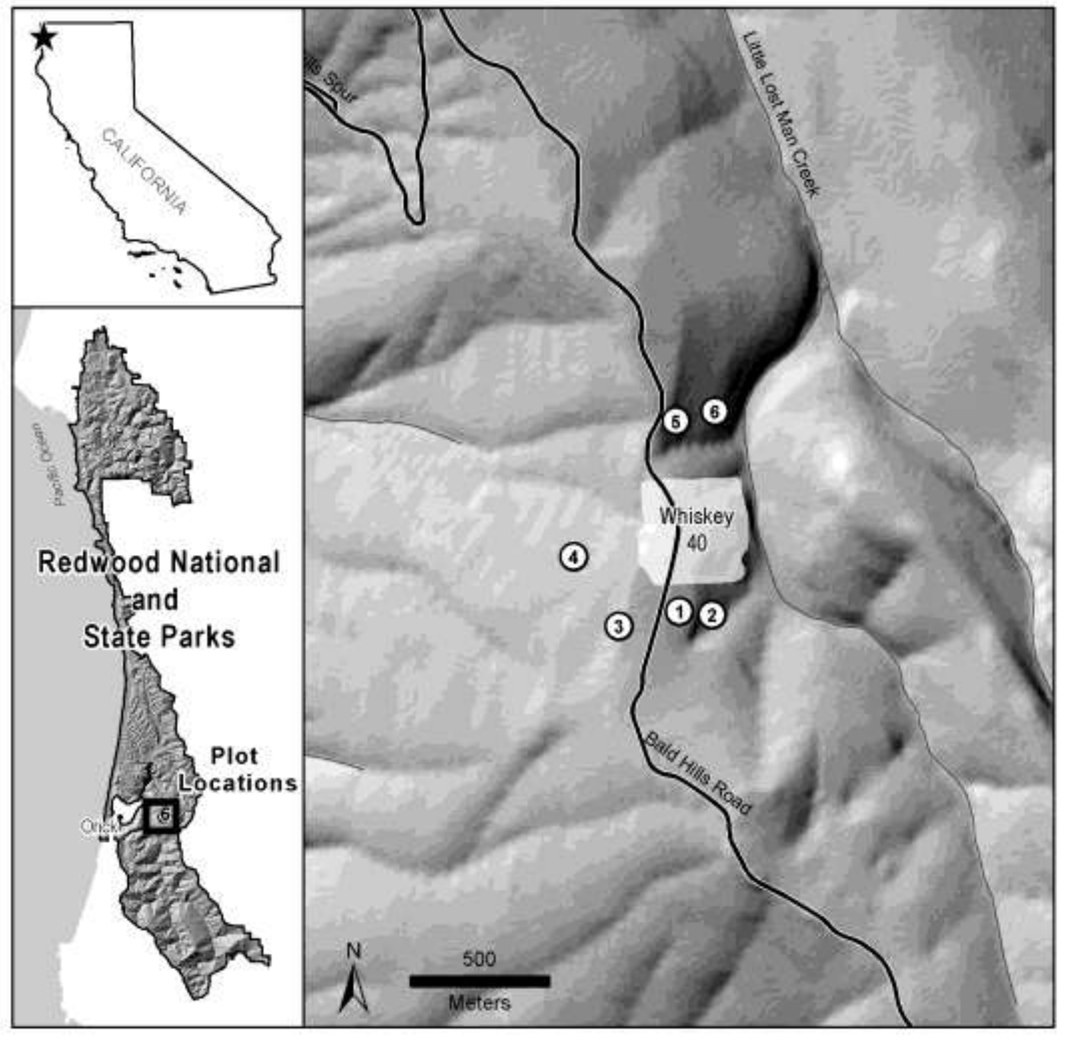
Plot statistics

<u>1995</u>
Stem density:
182 stems ha^{-1} (1 SD = 36)
% *Sequoia* = 33%

Basal area:
169 m^2 ha^{-1} (1 SD = 30)
% *Sequoia* = 59%

<u>2010</u>
Stem density:
182 stems ha^{-1} (1 SD = 37)
% *Sequoia* = 31%

Basal area:
175 m^2 ha^{-1} (1 SD = 35)
% *Sequoia* = 60%



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van Mantgem and Stuart, 2012 PSW-GTR-238

One hectare forest monitoring plots

Forest dynamics from 1995 to 2010

	Plot identifier	Recruitment rate (%)	Mortality rate (%)	Basal area gain ($m^2\ ha^{-1}\ year^{-1}$)	Basal area loss ($m^2\ ha^{-1}\ year^{-1}$)
All species	Plot 1	1.02	0.73	1.02	1.57
	Plot 2	0.35	0.64	1.04	0.36
	Plot 3	0.53	0.46	1.23	0.17
	Plot 4	1.01	0.59	1.02	0.82
	Plot 5	0.98	0.60	0.75	0.48
	Plot 6	0.31	1.16	0.78	1.41
	average	***0.70***	***0.70***	***0.98***	***0.80***
	95% CI	*0.46 to 0.94*	*0.58 to 0.99*	*0.85 to 1.1*	*0.41 to 1.28*
Sequoia only	Plot 1	0.11	0.67	0.42	0.40
	Plot 2	0.00	0.26	0.44	0.20
	Plot 3	0.11	0.11	0.92	0.02
	Plot 4	0.66	0.35	0.64	0.66
	Plot 5	0.25	0.13	0.21	0.26
	Plot 6	0.25	0.44	0.36	0.77
	average	***0.23***	***0.33***	***0.50***	***0.38***
	95% CI	*0.1 to 0.43*	*0.19 to 0.5*	*0.35 to 0.71*	*0.19 to 0.61*

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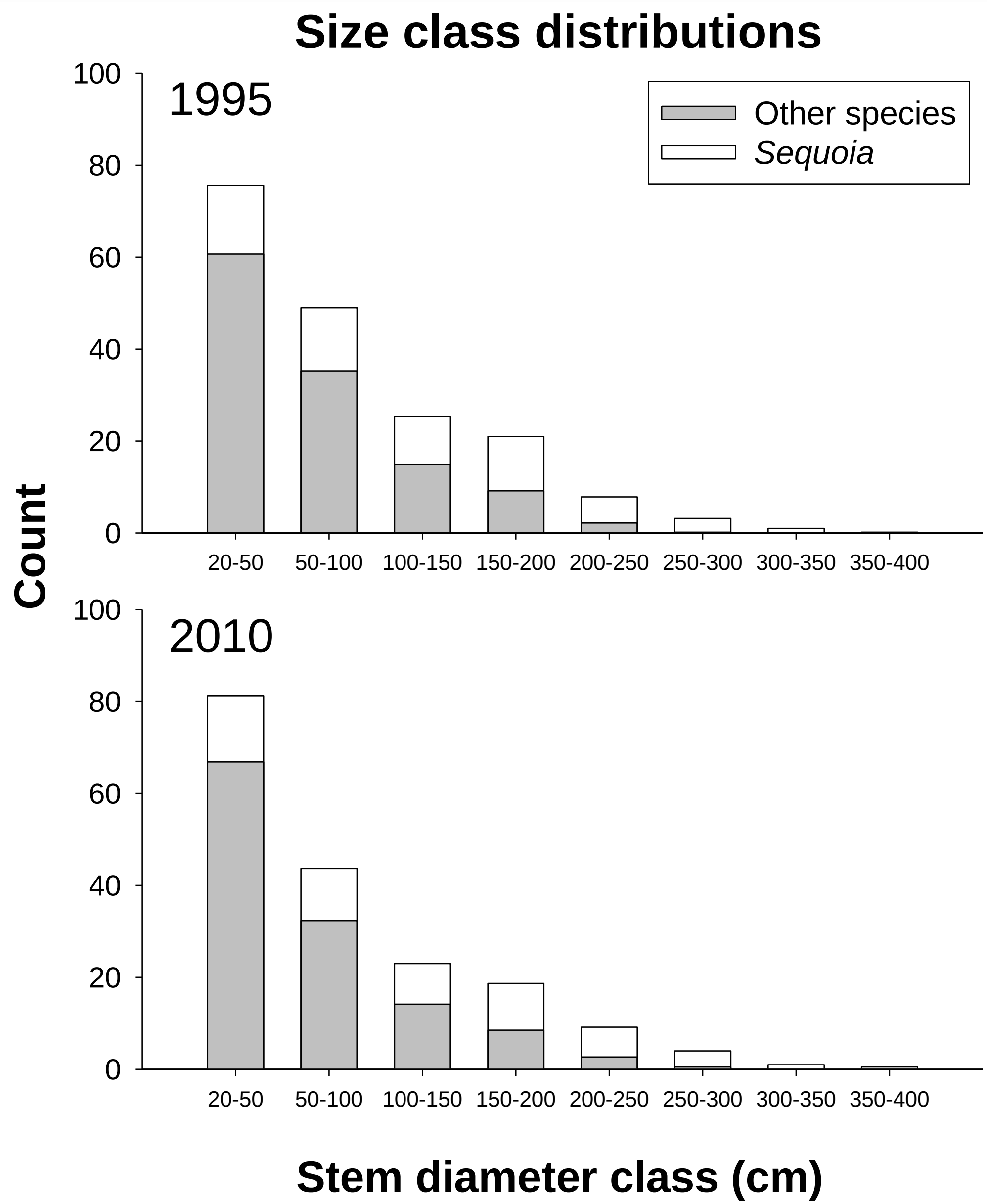
van Mantgem and Stuart, 2012 PSW-GTR-238

One hectare forest monitoring plots



<u>All Species</u>
Average M = + 0.002,
range = -0.388 to 1.612
P = 1.0

<u>*Sequoia*</u>
Average M = + 0.044,
range of M = -0.611 to 1.389
P = 0.049

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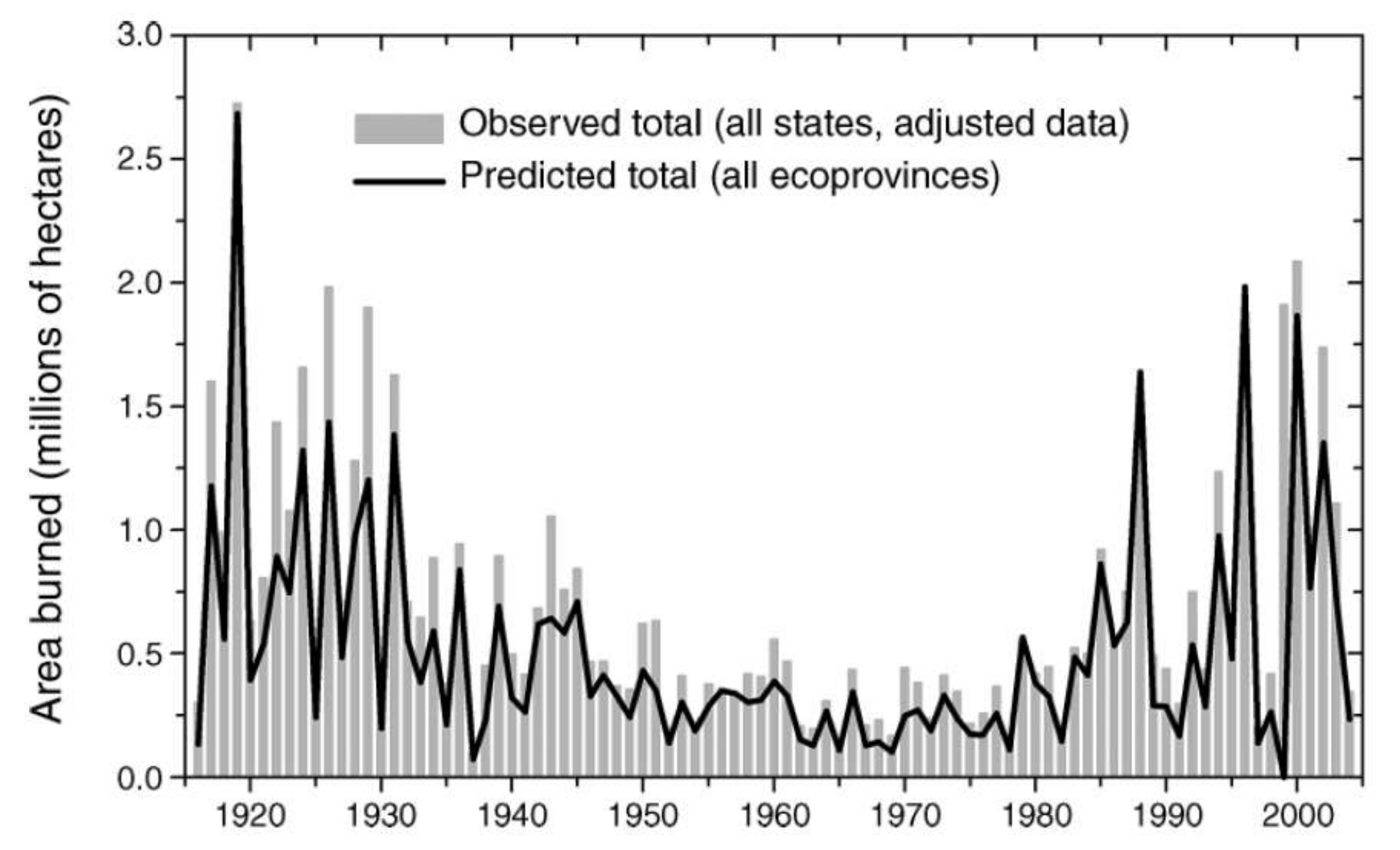
van Mantgem and Stuart, 2012 PSW-GTR-238

Credit: E. Knapp

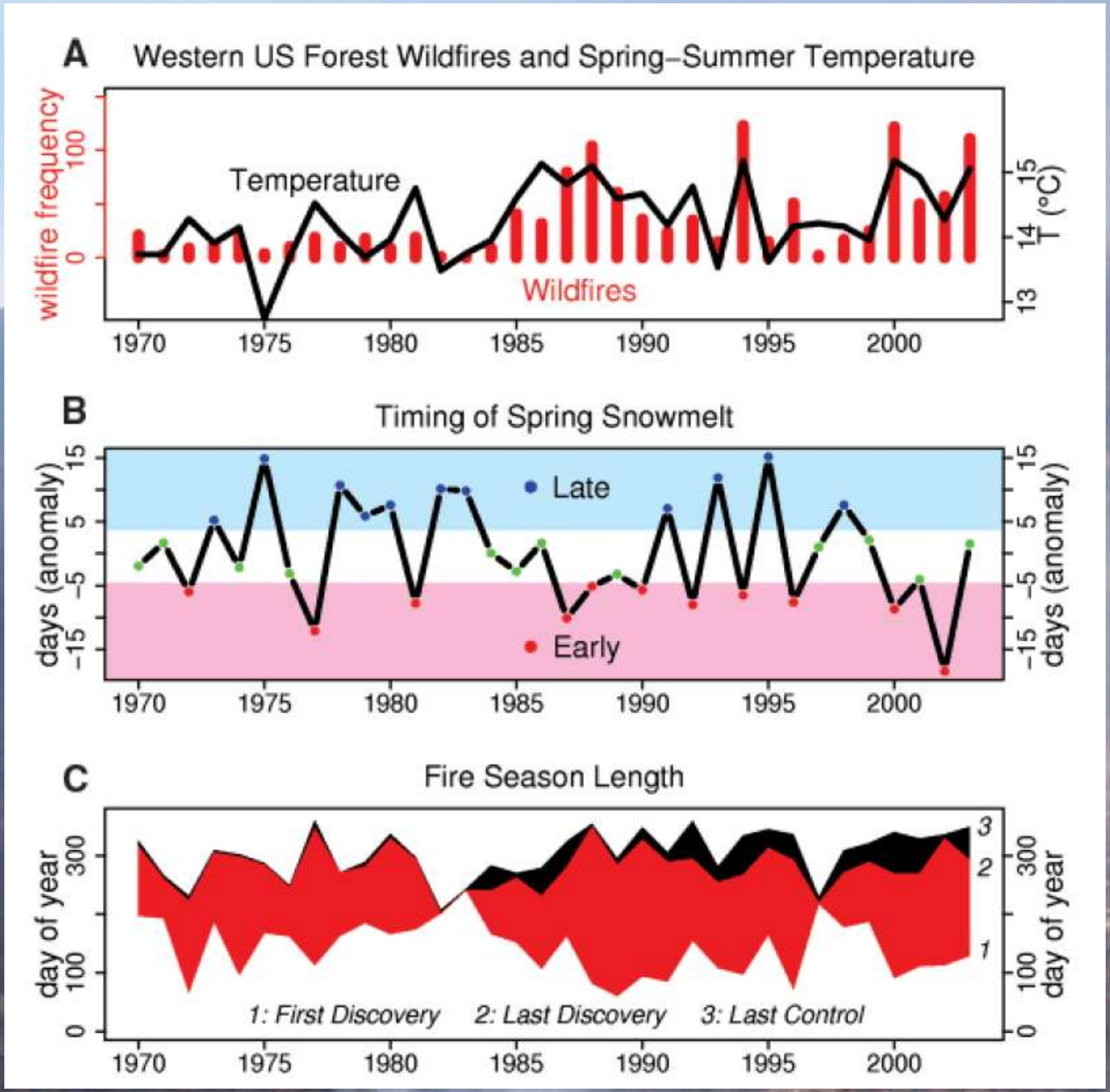
Changing climate = changing fire regime
Area burned annually is increasing



Littell *et al.* 2009, *Ecol. Appl.*

Credit: NPS

Changing climate = changing fire regime
The fire season is lengthening

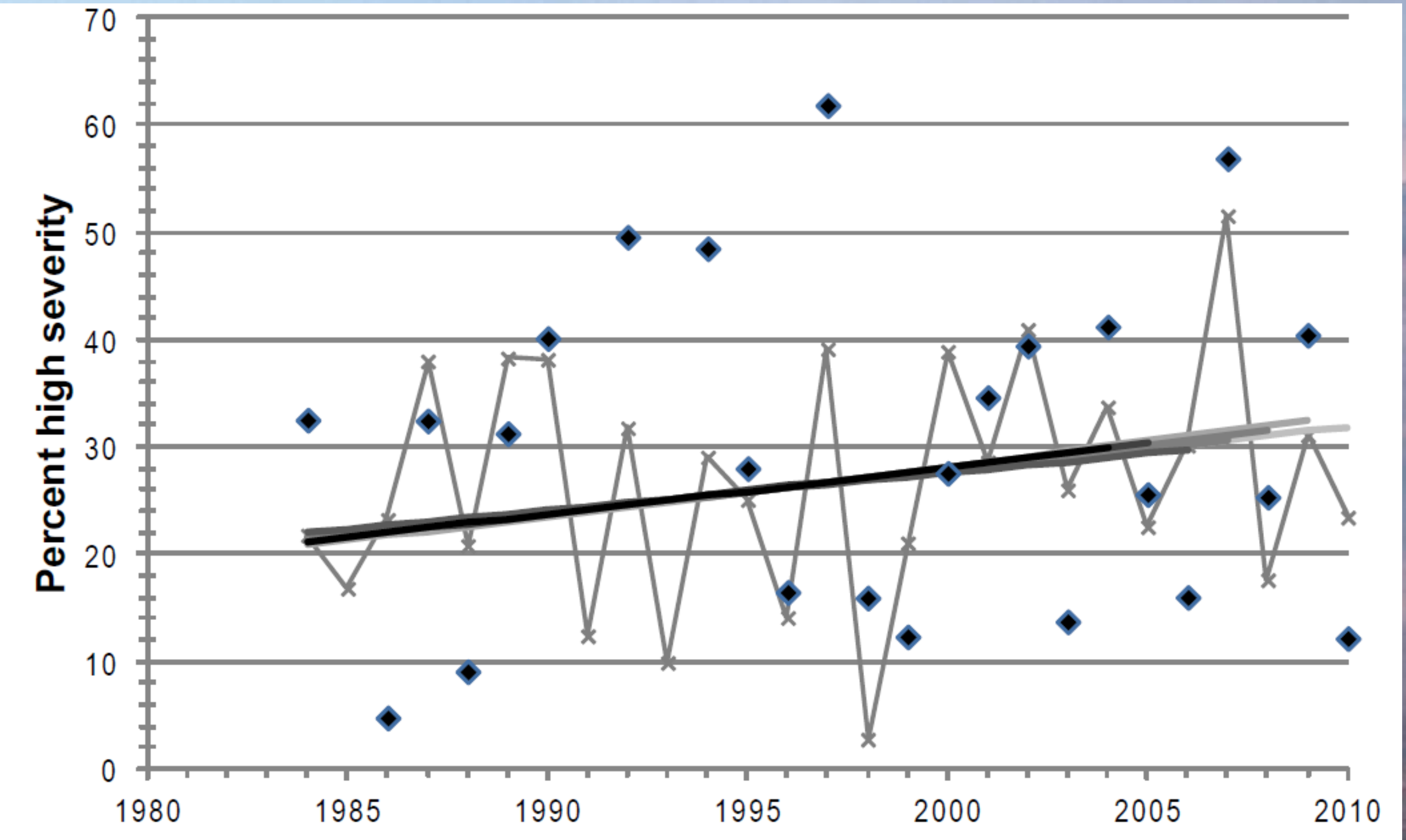


Westerling *et al.* 2006, *Science*

Credit: NPS

Changing climate = changing fire regime

High severity fire is increasing across the Sierra Nevada of California



Miller *et al.* 2009, *Ecosystems*,
Miller & Safford 2012, *Fire Ecol.*
(but see Miller *et al.* 2012, *Ecol. Appl.*)

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What does this mean for our forests?

Current NPS natural resources policy:

-- When possible, restore and maintain naturally-functioning ecosystems.

-- When this is not possible, “maintain the closest approximation of the natural condition.”

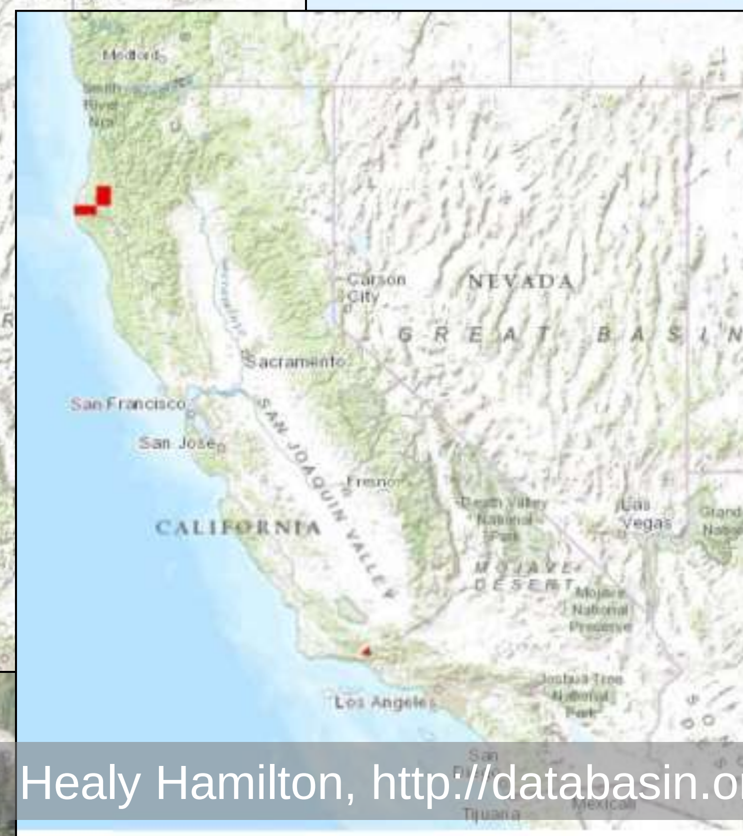
Credit: N. Stephenson

Expected changes to redwood populations

2010

2050

2090



Healy Hamilton, http://databasin.org/

Adapting to Climate Change

(Furniss, et al. 2009) http://www.fs.fed.us/ccrc/hjar/

Use adaptive management (mgmt as an ongoing experiment)

Reduce present threats (e.g., invasive species, disrupted fire regimes)

Monitor (essential to adaptive mgmt, change detection)

Integrate climatic change into management planning

(encourage landscapes that can accommodate change)

-- Assist species migrations?

-- Non-native genotypes?

-- More intense thinning?

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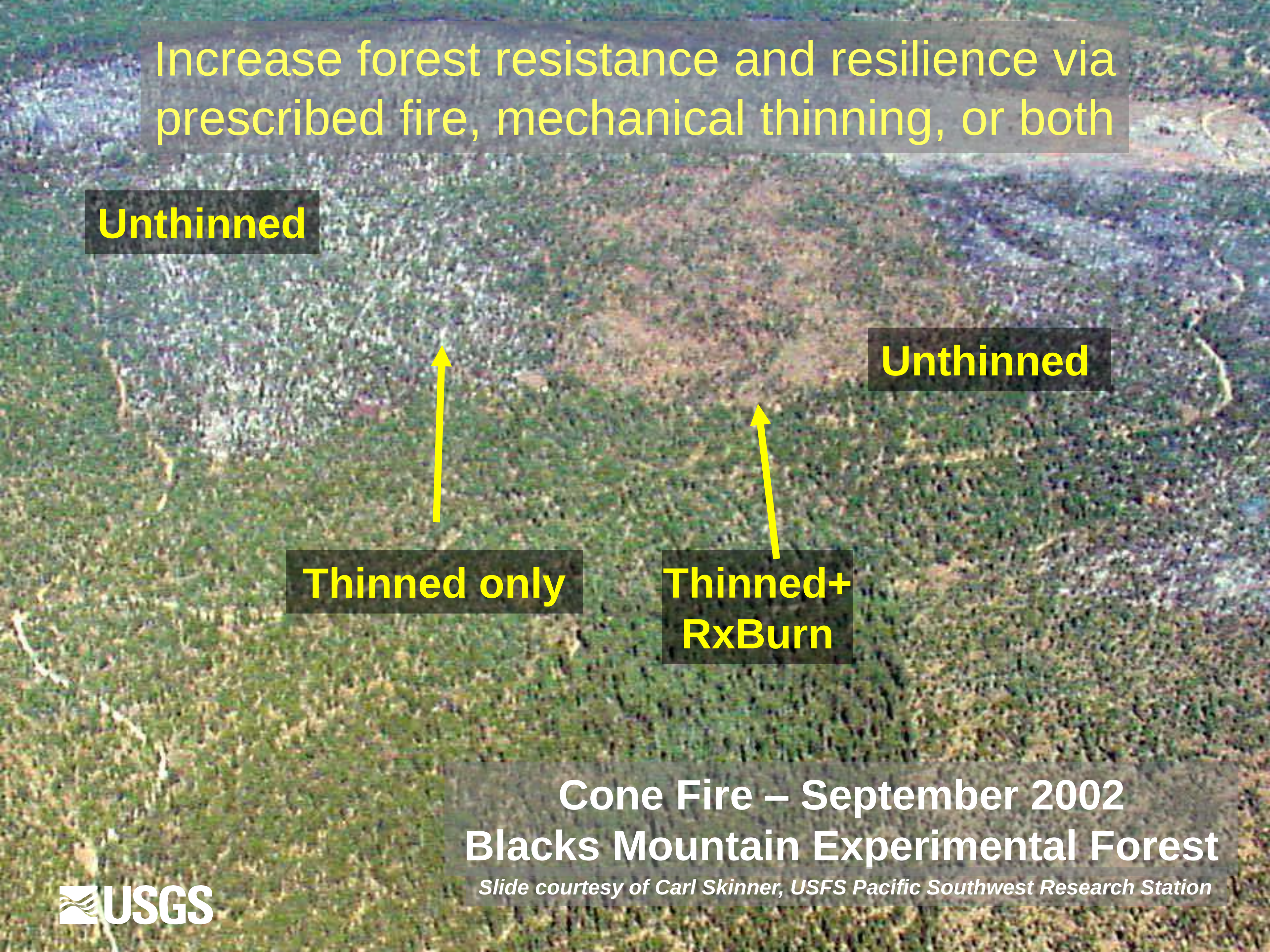
Increase forest resistance and resilience via prescribed fire, mechanical thinning, or both

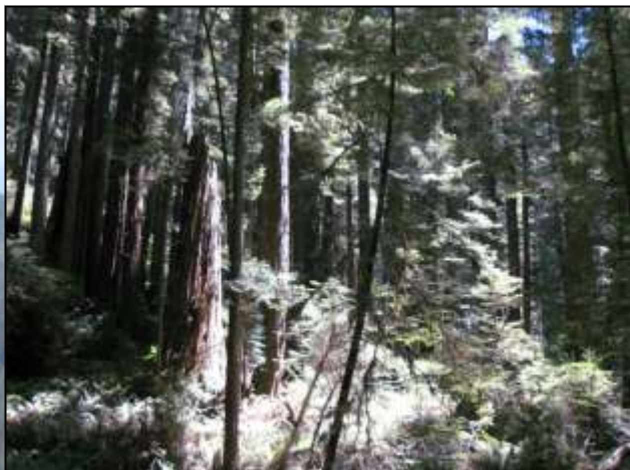


Cone Fire – September 2002
Blacks Mountain Experimental Forest

Slide courtesy of Carl Skinner, USFS Pacific Southwest Research Station

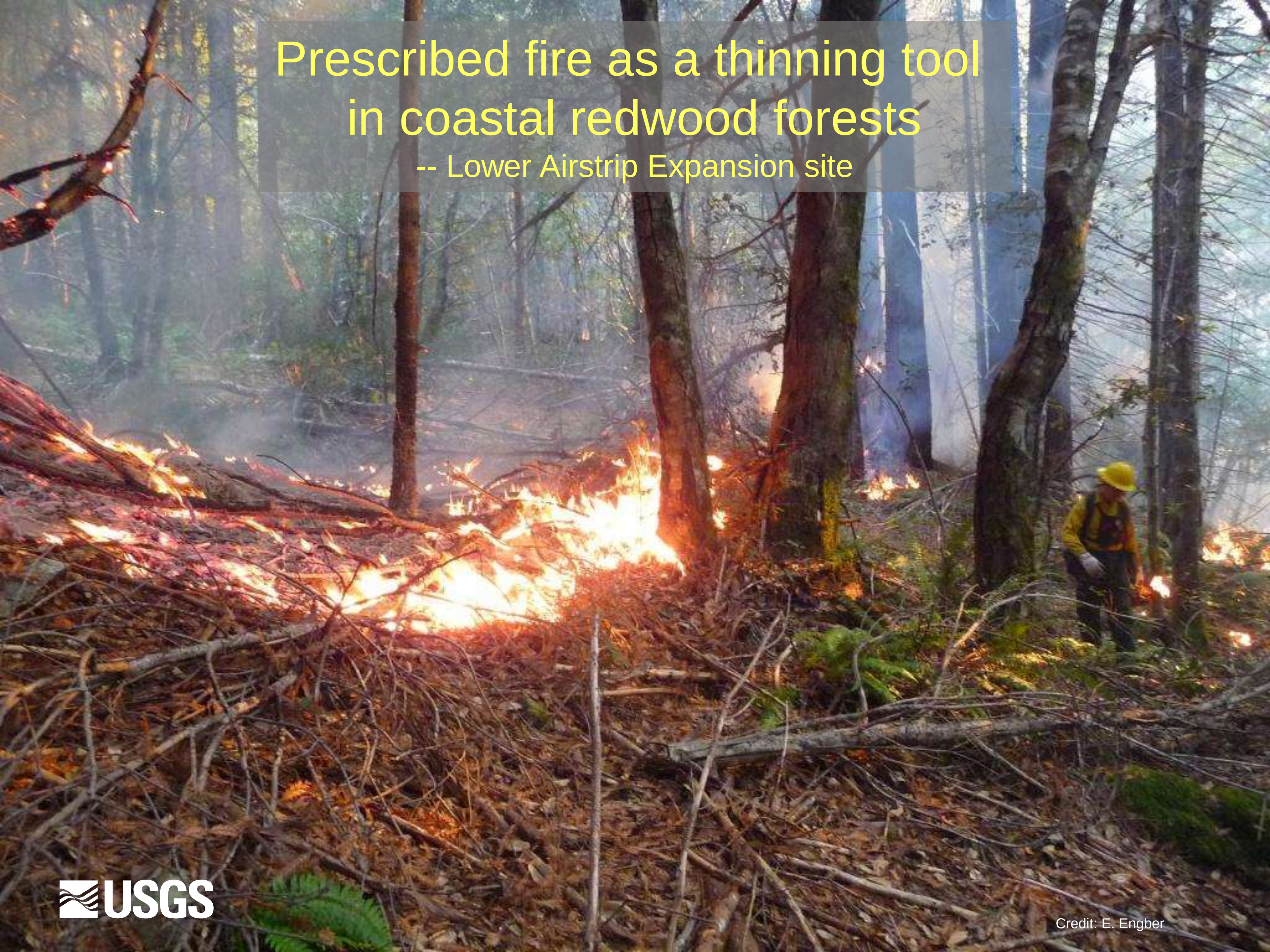
Does forest restoration increase resilience to drought?

Old-growth



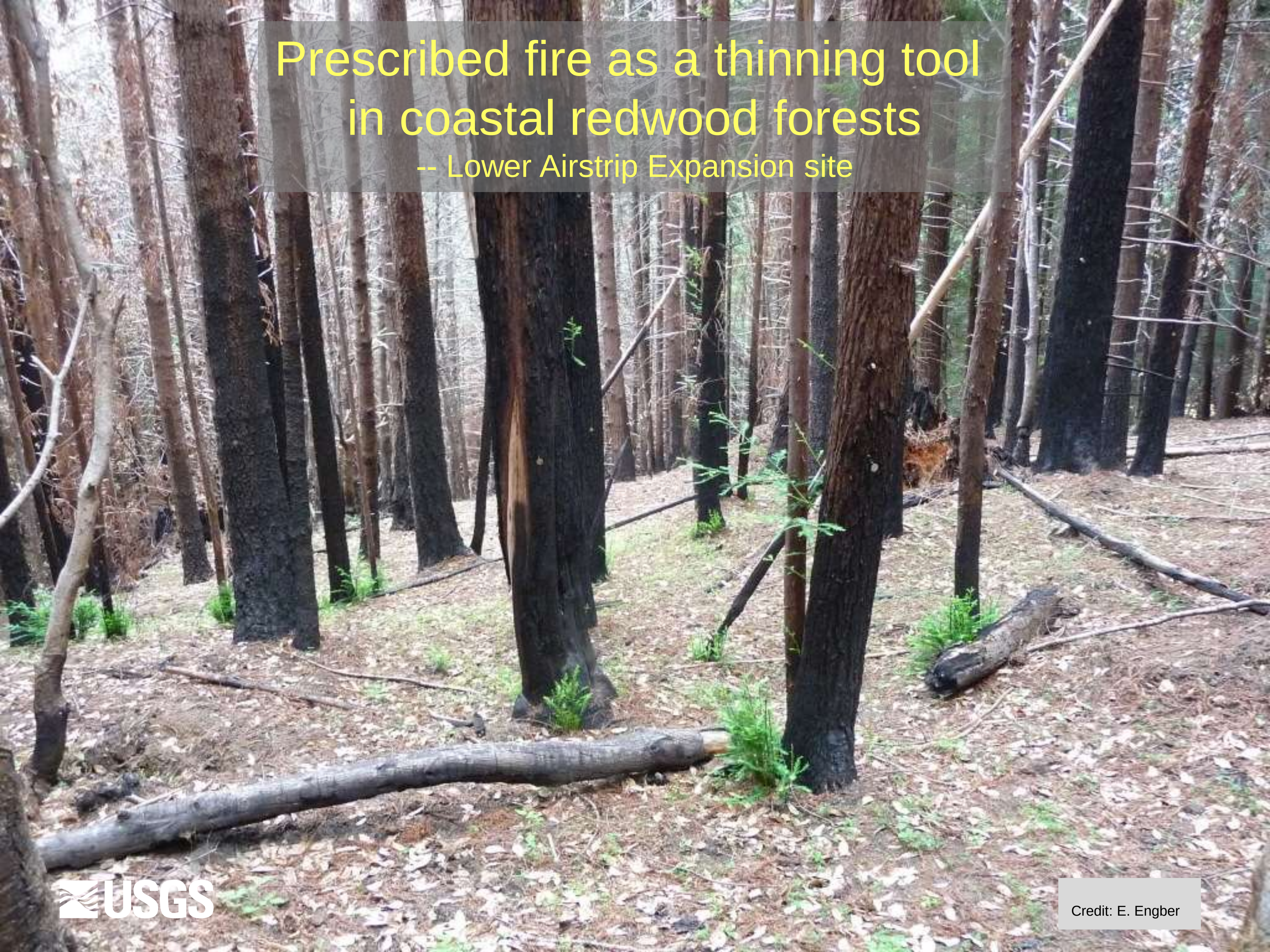
Second-growth

Second-growth: thin


Prescribed fire as a thinning tool in coastal redwood forests
-- Lower Airstrip Expansion site
USGS
Credit: E. Engber

Prescribed fire as a thinning tool in coastal redwood forests

-- Lower Airstrip Expansion site



The take home!

•Future environments will be novel, with no past analogs.

•Past conditions no longer provide an *automatic* target for mgmt.

•The future is uncertain, but we can still plan and act!

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Thanks!

Countless fire effects field crews, and data managers…
Jon Hollis, Laura Lalemand, Janelle Deshais.

National Park Service, USGS, Joint Fire Sciences Program

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